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FLEXIBLE DOWNDRAINS

**U.S. DEPARTMENT of AGRICULTURE FOREST SERVICE
EQUIPMENT DEVELOPMENT CENTER SAN DIMAS, CALIFORNIA**

Equipment Development and Test Report 7700-6

FLEXIBLE DOWNDRAINS

by

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JANUARY 1974

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ABSTRACT

Various experimental flexible downdrains for cross-road culverts were installed in test locations in the western Regions. After three years of field testing, the downdrains proving most satisfactory were those fabricated of neoprene-coated nylon and provided with grommets to hold them to the fill slope. Results of field testing, cost data, and life of downdrains are discussed.

* * * * *

A report on ED&T Project No. 1861 -
Engineering - sponsored by the Division
of Engineering.

INTRODUCTION

Water discharging from a culvert onto a hillside fill can develop a high velocity as it flows down the slope. The high velocity enables the water to gouge out the slope, quickly picking up quantities of sediment and carrying it to the stream channel below. The problem is to eliminate this erosion by devising a means of transporting the water from the culvert to the channel without disturbing the fill slope.

The conventional solution has been to attach a downdrain of corrugated metal pipe (CMP) to the outlet of the culvert. The downdrain then carries the water to the channel at the foot of the slope.

These CMP downdrains are of two basic designs, half-round and full-round. The half-round tends to twist, so it must be well-bedded and anchored at a minimum interval of 10 ft. Also, the half-round must be of a larger size than the culvert on which it is installed to prevent water from splashing over the sides. The full-round pipes cost more than the half-rounds. CMP downdrains are aluminum or galvanized steel. They are readily seen, and because of their shape they are not easily hidden by vegetation. They are expensive to fabricate, install, and maintain. They also require uniform slopes for proper support.

It was theorized that flexible downdrains constructed of a light, inexpensive material able to withstand rigorous environmental conditions commonly found in forests would eliminate some of the disadvantages of the CMP downdrains. Flexible materials, such as plastic and rubber, were suggested for this application. The Intermountain and Pacific Northwest Regions of the Forest Service have experimented with flexible plastic and rubber tubes with varying degrees of success. The Equipment Development Center evaluated downdrain materials similar to those used by these Regions and reported on the results in a Project Record dated July 16, 1969. Certain shortcomings of this downdrain design showed a need for further refinement of the design. One particular problem was lateral movement of the downdrains across the fill slope caused by the wind or by movement of water inside the downdrains. This report includes the results of field evaluations of flexible downdrains with these modifications. It presents a cost analysis comparing the cost of flexible tubes with that of the CMP pipe downdrains.

PROCEDURE - AN OVERVIEW

The first step to improving the design and lowering the cost of construction and maintenance of downdrains was to conduct a thorough evaluation of products that were commercially available at that time. It was determined that the new design would have to incorporate a material less costly and easier to maintain than corrugated metal pipe.

A search for materials suitable for use as downdrains was initiated. Since two of the Regions, the Intermountain and the Pacific Northwest, had already experimented with flexible plastic and butyl rubber tubes with varying degrees of success, downdrains of these materials were evaluated. Then, a market search was conducted for other flexible materials that might be useful. The twelve most promising materials were subjected to a screening process that included testing by an independent laboratory for such qualities as relative abrasion resistance, brittleness temperature, flammability, tensile strength, and other durability qualities. The three materials that most successfully fulfilled the screening requirements were then selected for construction of the test downdrains.

Downdrains were installed at sites selected by regional personnel in each of the six western Regions. ^{1/} There were initially 26 flexible downdrains installed. Modification to the flexible downdrains were found to be necessary after 1 year of testing. Seven additional modified downdrains were then installed.

The original downdrains were allowed to function in the field for 4 years, between 1968 and 1972, as a practical test of their usefulness. In addition to occasional checks by field personnel, each installation was inspected annually by an engineer from the Center. At the time of the inspection the engineer thoroughly examined the condition of the downdrain, the fill slope, and the road structure. He noted all defects and malfunctions, and interviewed field personnel for their experiences with the installations to determine what problems had occurred, what repairs they had made, and how they thought the design could be improved.

^{1/} See table 2, page 5.

MATERIALS

Laboratory Tests

The candidate materials were subjected to a series of tests that determined how well they possessed the qualities that the Center's engineers had determined were desirable for downrain materials. The nine qualities measured were:

1. Relative abrasion resistance.
2. Brittleness temperature.
3. Flammability.
4. Tensile strength.
5. Elongation at rupture.
6. Load required to initiate tear in unslit sample.
7. Shear strength.
8. Permanent change effected in tensile strength by exposure to high heat for an extended time.
9. Change in tensile strength effected by simulated sunlight and fog.

The tests were conducted by the Magnaflux Corporation of Los Angeles, a professional laboratory that specializes in materials testing. The results are shown in table 1.

Material Selection

Most of the materials did not do well enough in the tests to merit further consideration. Perflex estane film, Rhino #65 nylon-reinforced polyethylene, Franplas discharge hose, and Chrystalene polyethylene film exhibited a degradation in tensile strength of over 25 percent from the effect of simulated sunlight and fog. As the ability to withstand exposure without losing a significant amount of tensile strength is a prime requirement for downdrains, these four were eliminated.

The black polyethylene film was eliminated because of its inordinately low abrasion resistance.

Bu-Turf polybutylene film and butyl reinforced rubber tubing, one-ply insert neoprene and polyvinyl chloride film did not score well enough in the tests for shear strength and tensile strength. Butyl products were not considered unacceptable; however, their low strengths per unit weight were decisive in eliminating them.

Table 1. Summary of laboratory test results

Test Description & Units of Results	ASTM Test Method and Title		Material											
			But-Tuf Polyethylene Film 0.016" Thick	Polyvinyl Chloride Film, 0.030" Thick	Perflex Estane Film, 0.002" Thick	Rhino #45 Nylon Reinforced Polyethylene 0.007" Thick	Frampas Discharge Hose	Coverlite 45 oz/sq yd Black Nylon Reinforced Neoprene	One-Ply Inert Neoprene 15 oz/sq yd	Butyl Rubber Tubing, Reinforced	Relgard V Nylon Reinforced Vinyl 18 oz/sq yd (green)	Relgard N Nylon Reinforced Neoprene 16 oz/sq yd (black)	Chrysolene Polyethylene Film 0.016" Thick (red)	Polyethylene Film 0.010" Thick (black)
Relative abrasion resistance, parts per million weight loss per 1000 cycles.	D1044-56 modified	Resistance of Transparent Plastics to Surface Abrasion.	76.0	22.3	Sample tore during test.	134	7.1	85.9	69	51.1	7.8	22.9	Data not available	411
Brittleness temperature, °F	D746-64T	Brittleness Temperature of Plastics and Elastomers by Impact.	-55.4	-67.0	Less than -100	Less than -100	-30.6	-38.0	-59.4	-64.6	Less than -100	-54.2	Less than -100	Less than -100
Flammability, Inches per Minute	D568-61	Flammability of Plastics	13.3	Self Extng.	Nonburning	24.8	4.1	Nonburning	8.1	12	Self Extng.	24.2	9.7	11.7
Tensile strength, psi	D794-64T	Permanent Effect of Heat on Plastics	3710	2960	3890	8110	5520	11500	1290	713	4050	15400	2010	1760
Elongation at rupture, %	D794-64T	Permanent Effect of Heat on Plastics	227	350	457	23	70	20	217	350	20	37	640	215
Load required to initiate tear in unslit sample, lbs	D1938-62T	Resistance to Tear Propagation in Plastic Film and Thin Sheeting by a Single Tear Method	1.45	2.48	0.52	1.7	28.1	57.5	16.7	18.7	6.4	42.3	4.6	26
Shear strength, psi	D732-46	Shear Strength of Plastics	3340	1810	Greater than 853	1230	2480	4860	2640	2270	4520	13700	1240	2530
Permanent effect of exposure to 150°F for 4 hours; change in tensile strength, % $\frac{1}{I}$	D794-64T	Permanent Effect of Heat on Plastics	-6.2	0	+82	-0.9	-21.6	0	+81.4	-1.4	+12.6	-1.3	+1.9	0
Effect of simulated sunlight and fog; change in tensile strength, % $\frac{1}{I}$	D795-65 modified	Exposure of Plastics to S-1 Mercury Arc Lamp - Procedure B	+1.6	-4.7	-70.4	-52.7	-58.7	+4.3	+22.5	+8.0	+5.4	-3.2	-28.9	+97.2
Was Acceptable			No	No	No	No	No	Yes	No	No	Yes	Yes	No	No

$\frac{1}{I}$ +Indicates an increase in tensile strength.

-Indicates a decrease in tensile strength.

The three remaining materials, all of which were acceptable in the laboratory tests, were selected for the test downdrains. These were Coverlite 45 oz/sq yd black nylon reinforced neoprene, Relgard V nylon reinforced vinyl 18 oz/sq yd green, and Relgard N nylon reinforced neoprene 16 oz/sq yd black.

Throughout the remainder of this report, the Coverlite 45 oz/sq yd Relgard N neoprene-coated nylon cloth will be referred to as 45 oz neoprene, the Relgard N 16 oz/sq yd neoprene-coated nylon as 16 oz neoprene, and the Relgard V 18 oz/sq yd vinyl-coated nylon as 18 oz vinyl.

SITE SELECTION

Each of the western Regions (1 through 6) was asked to select an area that it considered suitable for a test site for downdrain installations. Table 2 lists these field test sites.

Table 2. Field test sites

Region	Forest	District	Road	Road No.
Northern (1)	Lolo	Missoula	South Side O'Brien	2141
Rocky Mountain (2)	Arapaho	Clear Crk.	Guanella Pass	--
Southwestern (3)	Santa Fe	Las Vegas	Johnson Mesa	10156.1
Intermountain (4)	Sawtooth	Fairfield	Couch Summit	70094
California (5)	Mendocino	Ukiah	Elk Crk.-Potter Valley	20N01.7
Pacific Northwest (6)	Umpqua	Tiller	Callahan	31310

DOWNDRAIN PLACEMENT

The original flexible downdrains were installed in the fall of 1968. Half of the downdrains were installed directly on the ends of the CMP with standard culvert bands as shown in figure 1. The other half were attached to corrugated metal elbows with standard culvert bands. This latter method directed the downdrain down the fill slope and eliminated the concentration of stress in the material where it joined the culvert. In approximately half of the installations involving elbows, anchoring wires and posts were placed as shown in figure 2 to help hold the downdrains and elbows in place. Appendix I shows detailed information on the materials, locations, and methods of attachment.



Figure 1. Standard culvert band.



Figure 2. Downdrain anchoring posts and wires.

EARLY FIELD OBSERVATIONS

The first failures were found in March 1969 by personnel of the Southwestern Region. Wind blew the unsecured tubes about, causing abrasion of the downdrain on the rocky fill slope. One downdrain was abraded so badly that it had to be removed and discarded. Three others were damaged, but not seriously enough to impair their effectiveness. An attempt to rectify this condition was made by staking and wiring at intervals of about 50 ft, and by lacing the bottom of the downdrain to a wire staked into the ground (see fig. 3). This did not prove satisfactory because down-drains were wrapped around the stakes by the wind. This led to a modification which incorporates grommets for staking down the downdrains.

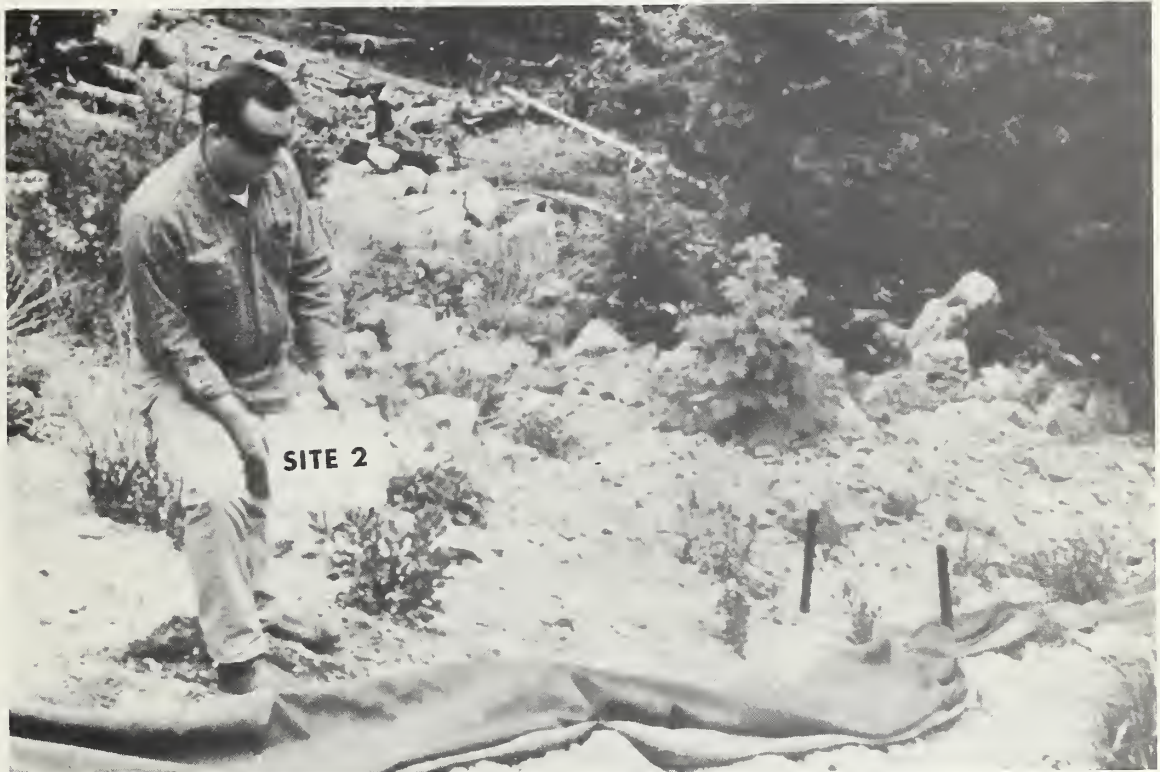


Figure 3. Post and wire tie down method used to prevent downdrains from blowing.

It was also noticed that the longitudinal seams that were sewn with a double stitching were enduring field punishment much better than those sewn with a single seam; this led to the modification of using double stitching.

Vandalism was an unexpected problem. Damage sufficient to at least partially destroy the intended function of the downdrain was observed on five of the sites. There was not sufficient information to determine if the color or type of downdrain

is significant in attracting vandals. One can only guess at reasons for the vandalism, but the material would seem to be attractive for general use such as a tarpaulin or ground cloth for campers.

Vinyl downdrains installed in the Intermountain Region were attractive to rodents and consequently were destroyed by them.

Further information concerning results of the first inspection is in Appendix I under "Comments After 8 Months."

MODIFICATIONS TO FLEXIBLE DOWNDRAIN DESIGN

As a result of the early field observations, seven new flexible downdrains were constructed and installed. These new downdrains were modifications of the original design to correct for the shortcomings noted in the previous section. The modified downdrains were installed at the test sites for evaluation concurrent with the remaining original designs.

The new downdrains were constructed from Relgard 16 oz neoprene. Grommets were spaced every 20 ft and double stitching at the seam was specified.

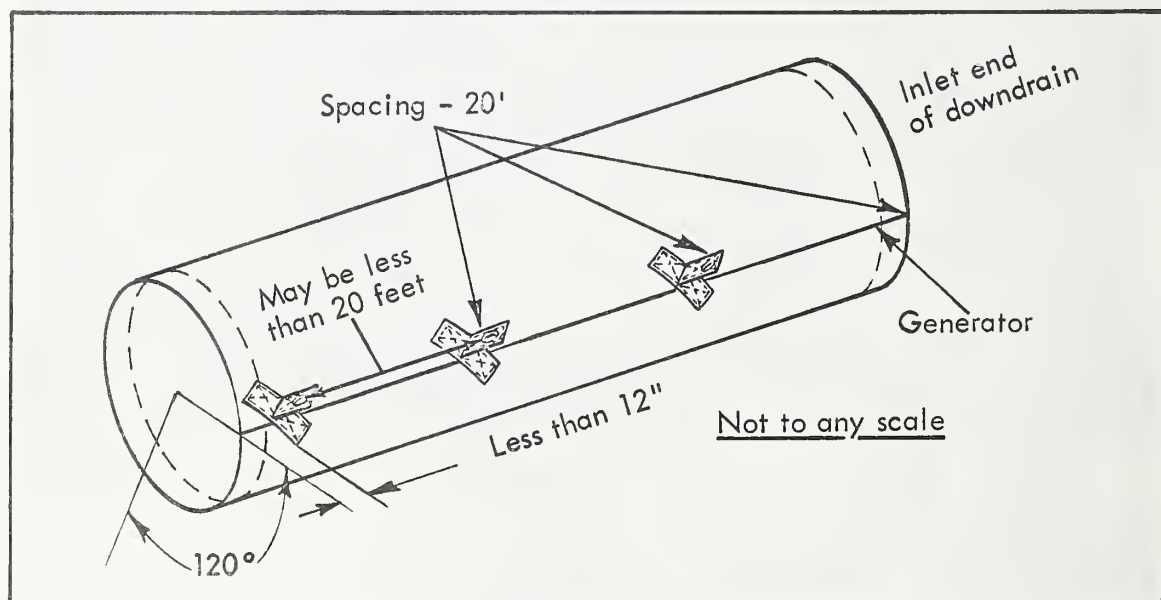


Figure 4. Modified downdrain design, two rows of grommets 120° apart.

Neoprene was utilized to minimize the rodent problem. The grommets allowed the downdrains to be staked to the ground preventing them from being blown about by the wind.



Figure 5. Grommet and stake used to prevent movement of down drain.

A new method, using nylon straps, of attaching the down drains to the CMP was also tried at this time. This was done in an attempt to simplify installation.

SUBSEQUENT OBSERVATIONS

All Down drains

An engineer from the Center inspected each of the sites during the summers of 1970, 1971, and 1972. All of the down drains had been subjected to some water flow with estimates ranging from a trickle to sustained rates of over one cu ft per sec. Water was flowing through several of the tubes at the time of inspection. Some were partially blocked by trees or other material that had fallen on them.

No failures were observed at the junction of the down drains and the corrugated metal pipe, even at those sites where elbows were not installed. However, one of the neoprene down drains installed without an elbow, and one with an elbow, were showing signs of weakness at this junction. None of the elbows, whether secured or unsecured, had slipped, so it was decided that the anchoring stakes would be unnecessary in future installations.

A common failure was the plugging of the down drain by the collapse of the erosion channel in which it has been placed. This failing would be avoided if the down drains were installed at the same time as the culvert, rather than waiting until the channel was already partially eroded. In cases where it is too late for simultaneous installations, the channel should be stabilized by filling in or tapering off the banks.

Soil and debris was a problem in culverts and down drains, including those down drains that had not been blown around the channel or bagged and become filled with soil. It is difficult to determine whether the down drain caused the plugging of the culverts, or vice versa. However, it seems likely that there is some combination of slope and flow below which the down drains will not be satisfactorily self-cleaning. Down drains, however, are almost invariably on a steeper slope than the culvert. Therefore, it seems probable that, except for extremely long tubes, water, and debris flow velocity sufficient to render the culvert pipes self-cleaning would be at least somewhat increased in the down drains, thus causing them to be self-cleaning as well.

All the down drains were subjected to a variety of environmental conditions, including variations in altitude, temperature, flows, snow, steepness of slopes, and soil types. The Umpqua Forest in the Cascade mountains of Oregon probably has the least severe environment. The Santa Fe Forest in the Sangre de Cristo range in New Mexico has high winds, while the Lolo Forest in Montana and the Arapaho Forest in Colorado, both of which are in the Rockies, pose the most serious freeze-thaw conditions. The test sites of the Sawtooth Forest in the Sawtooth range in Idaho suffer from rodent infestations, while the Mendocino Forest in the Coast range of California has very high flows during the winter rains.

Rocks caused some damage to five down drains during the tests, but did not cause any failures. Perhaps in areas immediately upstream of the culvert inlet where small, sharp, fractured rocks are numerous and are subject to move with the flow of water, other materials such as corrugated metal pipe, should be used.

For further information concerning the results of three of the inspection tours see Appendix I, which lists the condition of each of the down drains after exposures of 20, 33, and 45 months.

Field observations of the outlets of flexible down drains indicate that they work as good energy dissipators. This may be explained in theory because a flexible down drain assumes the shape of the water flowing through it. Hence, it always flows full and there is no free surface. The tubing is exerting a resistive force on all of the water's surface, thus reducing the velocity. The flexible down drain follows the contours of the ground surface on which it rests; the roughness of the latter tends to slow down the water's movement.

Modified Down drains

Three annual inspections showed that Relgard 16 oz Neoprene with grommets were very successful.

Deterioration of neoprene was caused by sunlight and resulted in detectable damage, but no failures. The greatest amount of material deterioration was on the high, hot, southern exposure slopes of the Santa Fe National Forest.

The Mendocino National Forest installed two modified, grommited, neoprene down-drains during 1969 near the sites of the original installations. One of the units was in excellent condition. The second was installed on a fill slope that had previously slipped and destroyed a 30-in. corrugated metal pipe. A great deal of earth slid down on top of the downdrain, completely destroying it.



Figure 6. Fill-slope failure--30-in. downdrain.

The Umpqua National Forest installed two modified downdrains on newly placed culverts in 1969. After 33 months both tubes were in perfect condition, but the nylon attachment strapping had failed because of weathering. Figure 7 shows one of the installations.

Modified downdrains were also installed on the Sawtooth National Forest and the Santa Fe National Forest in 1969. Except for complete deterioration of the nylon attachment straps the downdrains were in excellent condition after 33 months of use.



Figure 7. Pacific Northwest Region down drain installation.

LIFE OF DOWNDRAINS

One important consideration of users of downdrains is design life. Not enough data have been acquired from this study to make a mathematical prediction of the design life of the flexible downdrains. However, certain observations can still be made. The most common causes of damage and failure can be attributed to errors in installation or other human failings. Damage caused by vandalism, unsuitable installation, and erosion channel sloughing caused approximately 57 percent of the failures. Failures caused by improper attachment methods, wind action, and rodents were overcome by improving the design. Vandalism can be combated by either making the material indestructible, or if this is impossible by making the down drain of as unobtrusive a material as is possible. Material decomposition, such as that caused by sunlight, is not a serious problem. In normal service, it is likely that factors other than aging and weakening of the material will ultimately cause down drain failure.

Several of the vinyl film flexible downdrains installed by the Pacific Northwest Region on the Umpqua National Forest, prior to this project were also inspected annually. Of the six installed, after 6 years of use five are in fair condition, although showing some signs of the material weakening. These are in a well sheltered site with little wind and sunlight.

Neoprene downdrains installed in locations where flows were not severe show very little material change in 3 years.

From what data is now available, it seems reasonable to say that between one-half and two-thirds of the downdrains should remain in service for at least 5 years.

COST COMPARISON

Table 5 shows a cost comparison between half-round metal downdrains, full-round metal downdrains, and flexible downdrains of the improved design for the three most commonly encountered culvert sizes. Installation costs are based on estimates from the Angeles National Forest for the metal downdrains, and on Equipment Development Center experience with the flexible downdrains. Transportation costs are not included in either estimate. Labor costs for full-round metal downdrain installation were estimated at \$150 each, independent of size, while those for the installation of half-round metal downdrains were figured at \$100. Installation times in the field for flexible downdrains not using anchoring posts or elbows range from 5 minutes to one-half hour, so the table below uses \$3 labor cost. ^{2/} It is possible that the cost shown for the flexible downdrains could be somewhat reduced for large orders.

No long-term cost analysis was attempted because of insufficient data on the life of either metal downdrains, half-round or full-round, or flexible downdrains.

Table 5. Initial cost comparison ^{1/}

Culvert Size	Full-Round CMP	Half-Round CMP	Relgard. N 16-oz
12 in.	\$290	\$217	\$121
18 in.	344	267	172
24 in.	399	322	223

^{1/} Estimate based on 50-ft installation of 50 percent slope.

CONCLUSIONS

1. From the standpoints of durability, ease of installation, and cost, the 16-oz neoprene downdrains appear to be the best. Grommets and stakes are necessary to prevent the downdrain from being blown around by the wind, and especially from falling into the erosion channel that inevitably exists when the downdrain is installed a long time after road construction is finished.

2. Anchoring stakes, wires, and elbows at the outlet of the culvert pipe are not necessary.

^{2/} These are relative costs only and are not to be used for estimating purposes.

3. The nylon strap attachment method has proved unsatisfactory.
4. The design life of flexible downdrains has not been firmly established. It seems probable, though, that between one-half and two-thirds of all properly installed improved downdrains will have a life exceeding 5 years.

RECOMMENDATIONS

1. Interim Specification 7100-001b, Downdrains, Flexible, Coated Fabric, describing grommeted neoprene downdrains, should be used for purchasing of all flexible downdrains.
2. Grommets and stakes used to hold the downdrain to the slopes should be used.
3. All downdrains should be attached to the culvert pipe with a standard corrugated metal culvert band.

APPENDIX I

SUMMARY OF DOWNDRAIN INSPECTION RESULTS

SUMMARY OF DOWNDRAIN INSPECTION RESULTS

LOCATION	TYPE OF DOWNDRAIN	ATTACHMENT	HOLD/DOWN	COMMENTS AFTER 8 MONTHS	COMMENTS AFTER 70 MONTHS	COMMENTS AFTER 23 MONTHS	COMMENTS AFTER 45 MONTHS
R1	Relgard Vinyl 18 oz Green	30° Elbow and Standard Band	None	Serviceable - 12 small holes from rock punctures.	Little change.	Little change.	Slight Actinic deterioration. $\frac{1}{2}$
	Reeves Coverlite 45 oz Black	Standard Band	None	No damage or wear.	Slit entire length with knife, but still functioning.	Little change, slight sign of Actinic deterioration where downdrain joins CMP.	Slight Actinic deterioration, still functioning despite slit.
	Reeves Coverlite 45 oz Black	40° Elbow Post & Wire	None	Stolen from culvert.	—	—	—
	Relgard Neoprene 16 oz Green	Standard Band	None	Stolen from culvert.	—	—	—
R2	Relgard Vinyl 18 oz Green	30° Elbow	None	One small rock puncture.	Outlet end buried, downdrain discharging through large seam rip (eration channel) sloughing in on downdrain). Downdrain buried in straw and ice, but still flowing freely.	Tube cut off 10 ft from CMP, otherwise in good condition.	—
	Relgard Vinyl 18 oz Green	20° Elbow Post & Wire Standard Band	None	One small rock puncture.	Downdrain in good condition, but CMP plugged at its inlet.	Downdrain removed by county maintenance worker. $\frac{1}{2}$	—
	Relgard Neoprene 16 oz Black	30° Elbow Standard Band	None	No damage.	No damage.	Downdrain removed by county maintenance worker. $\frac{1}{2}$	—
	Relgard Neoprene 16 oz Black	Standard Band	None	No damage.	Material in good condition, but plugged with soil.	Downdrain removed by county maintenance worker. $\frac{1}{2}$	—
	Relgard Neoprene 16 oz Black	20° Elbow Post & Wire Standard Band	Post & Wire	Plugged (soil had collected in twisted tube - insufficient hold-down); single seam torn (single seam had torn while double seam was OK).	Downdrain has blown and bagged collecting large hole at first set of stakes - downdrain considered failed. Seam tear has not enlarged.	Seam tear extended nearly entire length of downdrain.	Rock abrasion inside and out on bottom of tube. All exposed nylon threads are rotten and weak.
	Relgard Neoprene 16 oz Black	30° Elbow Standard Band Post & Wire	Post & Wire	No damage or wear.	No damage or wear.	No damage, slight wear.	Actinic deterioration on top in horizontal lines where material flexes. Tube 95% perfect.
	Reeves Coverlite 45 oz Black	30° Elbow Standard Band Post & Wire	Post & Wire	No damage, slight wear, starting to weather check.	Several small holes worn through, show weather checks on top of tube.	Several holes where sharp rocks have abraded through bad weather checks.	—
	Relgard Vinyl 18 oz Green	Standard Band	None	Destroyed - wind, insufficient hold-down. $\frac{4}{4}$	—	—	—
	Relgard Neoprene 16 oz Black	Standard Band	Grommets	Replacement downdrain stolen. $\frac{2}{2}$	—	—	—
	Relgard Vinyl 18 oz Green	Standard Band Post & Wire	None	Few small injuries and holes from wind and rocks wearing through.	Only slightly deteriorated from 12 months ago.	Few small holes, one 18" rip in seam.	No change.
R4	Relgard Vinyl 18 oz Green	30° Elbow Standard Band Nylon Straps	None	Destroyed - rodents. $\frac{4}{4}$	—	—	—
	Relgard Neoprene 16 oz Black	30° Elbow	Grommets	Excellent condition. $\frac{5}{5}$	Slight signs of Actinic deterioration.	Downdrain material still in good condition. Nylon attachment strap has deteriorated badly.	—
	Relgard Vinyl 18 oz Green	30° Elbow Standard Band	None	Destroyed - rodents. $\frac{4}{4}$	—	—	—
	Relgard Neoprene 16 oz Black	30° Elbow Nylon Straps	Grommets	Excellent condition, slight discoloration. $\frac{2}{2}$	Downdrain material excellent condition, nylon attachment strap deteriorated badly.	Excellent condition except strap.	—
	Relgard Neoprene 16 oz Black	30° Elbow Standard Band	None	Slightly twisted by wind.	No change.	Exposed threads showing signs of weakening. Some small holes worn in bottom of tube.	Blown and twisted by wind again, some soil inside, but not plugged.
	Relgard Neoprene 16 oz Black	30° Elbow Standard Band	None	Slightly filled with soil - still passing water - where slope decreased to about 10% (about 4 ft from outlet) plugging occurs.	No change, still partly filled with soil.	Slight Actinic deterioration where downdrain joins CMP, still in outlet end.	Slit in last 4 ft of downdrain.
	Relgard Neoprene 16 oz Black	30° Elbow Standard Band	None	Slightly twisted and slightly filled with soil.	No change.	Little change.	Looks very good.

SUMMARY OF DOWNDRAIN INSPECTION RESULTS (Continued)

LOCATION	TYPE OF DOWNDRAIN	ATTACHMENT	HOLDDOWN	COMMENTS AFTER 8 MONTHS	COMMENTS AFTER 20 MONTHS	COMMENTS AFTER 33 MONTHS	COMMENTS AFTER 45 MONTHS
85	Reeves Coverlite 45 oz Black	30° Elbow Standard Band	None	No damage.	General condition good. Few small abrasions and holes. Slight surface chalking.	Little change.	Little change, one small hole.
	Reeves Coverlite 45 oz Black	30° Elbow Standard Band	None	No damage.	Slight surface chalking.	No change.	Generally good condition, abrasion at outlet, otherwise good. No harm to fabric or function of downdrain and CMP.
	Relgard Vinyl 18 oz Green	30° Elbow Standard Band Post & Wire	None	Destroyed by flood.	---	---	---
	Relgard Vinyl 18 oz Green	30° Elbow Standard Band	None	Destroyed by flood.	---	---	---
	Relgard Neoprene 16 oz Black	Standard Band	Grommets	Inlet end plugged.	Large rock holes. Abused areas. Inlet had been cleaned out.	Some material deterioration.	---
	Relgard Neoprene 16 oz Black	Standard Band	Grommets	Improperly installed. Fill was slipping.	Destroyed by landslide. Both CMP and tubing ran out.	---	---
86	Relgard Vinyl 18 oz Green	Standard Band	None	No damage.	Downdrain was cut off by vandals but left on site. Reinstalled, and in excellent condition.	No change.	Holes throughout entire length of invert. Small gully starting to form.
	Relgard Vinyl 18 oz Green	Standard Band	None	No damage.	No damage.	Minor discoloration - Actinic deterioration.	4 ft long slit. May have split from water pressure.
	Relgard Neoprene 16 oz Black	Standard Band	None	No damage, end partially blocked by fallen log.	No damage.	Downdrain in excellent condition.	Downdrain in excellent condition.
	Relgard Neoprene 16 oz Black	30° Elbow Standard Band Post & Wire	None	No damage.	No damage, but tube partially buried by eroded channel sloughing in. CMP separated one length (10') from outlet because downdrain became filled with water and the weight pulled the pipe apart.	Downdrain still clogged, and pipe still pulled apart. Downdrain material is in good condition.	No change.
	Relgard Neoprene 16 oz Black	Nylon Strap	Grommets	Excellent condition.	Nylon attachment band failed, otherwise excellent.	Excellent condition.	---
	Relgard Neoprene 16 oz Black	Nylon Strap	Grommets	Excellent condition.	Nylon attachment band failed minor checks on seam/thread.	Covered by road construction soil, material in good condition.	---

- 1/ The action of short-wavelength radiant energy. in this case produced by the sun.
 2/ Downdrains removed by county maintenance workers prior to steam cleaning. Not replaced.
 3/ Very windy at all sites in Region 3.
 4/ This downdrain replaced by that immediately following on the list.
 5/ This downdrain replaces that immediately preceding on the list.

APPENDIX II

INSTALLATION INSTRUCTIONS FOR FLEXIBLE DOWNDRAINS

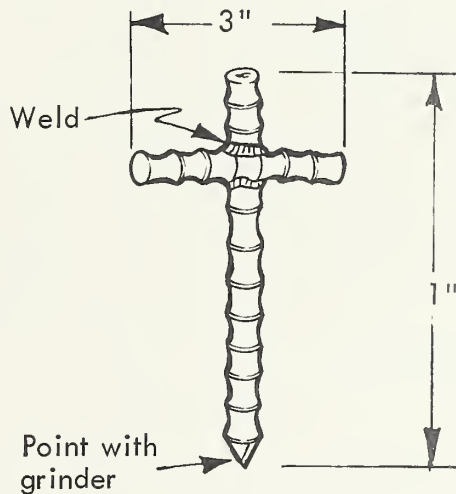
1. Fabricate one stake for each grommet. The stakes should be made of 1/2-in. reinforcing rod, or equivalent. A cross piece of 1/2-in. rod, 3 in. long, should be welded one inch from the upper end of the stake. The stake should be about 1 ft long, and pointed on the lower end. If used in soft or sandy soils, the stake must be longer.

2. Attach the inlet end of the downdrain to the culvert outlet. Use a standard CMP band.

3. Unroll the downdrain down the fill slope. Make sure that the outlet end is on solid ground, preferably rock. Make sure also that the downdrain is not in the ditch, in a position where slough is likely to cover it.

4. Stake each grommet down.

This installation procedure should take one man no more than a half-hour.



APPENDIX III

LIST OF MANUFACTURERS

LIST OF MANUFACTURERS

Petrotex Chemical Corp. 8600 Park Place Blvd. Houston, Texas 77001	-	Bu-Turf polybutylene film 0.016" thick
Plastimayd Corp. 2204 S.E. Seventh Street Portland, Oregon 97214	-	Polyvinyl chloride film 0.030" thick
Union Carbide Food Products Division 6733 West 65th Street Chicago, Illinois 60638	-	Perflex estane film 0.002" thick
Raven Industries Box 1007 Sioux Falls, South Dakota 57101	-	Rhino #65 nylon reinforced polyethylene 0.007" thick
Franklin Fibre-Lamintex Corp. East 13th Street & Gov. Printz Blvd. Wilmington, Delaware 19899	-	Franplas discharge hose
Reeves Brothers, Inc. New York, New York	-	Coverlite 45 oz/sq yd black nylon reinforced neoprene
Rubber Craft Corporation 1800 West 220th Street Torrance, California 90507	-	One ply insert neoprene 15 oz
Carlisle Tire & Rubber Division Carlisle, Pennsylvania 17013	-	Butyl rubber tubing, reinforced
Chrystal-x Corp. Second and Pine Streets Darby, Pennsylvania 19023	-	Chrystalene polyethylene film 0.016" thick red
Monsanto Co. 200 North Seventh Street Kenilworth, New Jersey 07033	-	Polyethylene film, 0.010" thick (black)
Reliance Plastic & Chemical Corp. 110 Kearney St. (P.O. Box 2627) Patterson, New Jersey 07509	-	Relgard V nylon reinforced vinyl 18 oz/sq yd (green)
	-	Relgard N nylon reinforced neoprene 16 oz/sq yd (black)

